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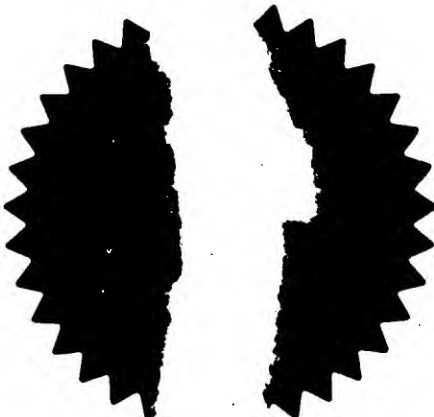
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Dated 21 FEB 2001



05APR00 0527170-1 002805  
P11/7700 0.00-0008281.8

## Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)



The Patent Office

Cardiff Road  
Newport  
Gwent NP9 1RH

1. Your reference

99R156/R.IB

2. Patent application number

(The Patent Office will fill in this part)

0008281.8

04 APR 2000

3. Full name, address and postcode of the or of each applicant (underline all surnames)

The BOC Group plc, Chertsey Road, Windlesham, Surrey, GU20 6HJ  
Patents ADP number (*if you know it*)

If the applicant is a corporate body, give the country/state of its incorporation

884627002 ✓

England

4. Title of the invention

Improvements in Reciprocating Machines

5. Name of your agent (*if you have one*)

"Address for service" in the United Kingdom to which all correspondence should be sent (*including the postcode*)

Roger James Bousfield

The BOC Group plc, Chertsey Road, Windlesham, Surrey, GU20 6HJ

Patents ADP number (*if you know it*)

973131002 ✓

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (*if you know it*) the or each application number

Country

Priority application number  
(*if you know it*)

Date of filing  
(*day / month / year*)

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application

Date of filing  
(*day / month / year*)

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (*Answer 'Yes' if:*

- a) any applicant named in part 3 is not an inventor, or
  - b) there is an inventor who is not named as an applicant, or
  - c) any named applicant is a corporate body.
- See note (d))

Yes

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form

Description 0  
3

Claim(s) 1

Abstract 0

Drawing(s) 1

10. If you are also filing any of the following, state how many against each item.

Priority documents 0

Translations of priority documents 0

Statement of inventorship and right to grant of a patent (Patents Form 7/77) 0

Request for preliminary examination and search (Patents Form 9/77) 1

Request for substantive examination (Patents Form 10/77) 0

Any other documents (please specify) 0

11.

I/We request the grant of a patent on the basis of this application.

Signature

Date

3 April 2000

12. Name and daytime telephone number of person to contact in the United Kingdom

Roger Bousfield  
(01276) 477612

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Continuation sheets of this form

Description

0

3

Claim(s)

1

Abstract

0

Drawing(s)

1

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to grant of a patent (Patents Form 7/77)

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Any other documents  
(please specify)

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### **IMPROVEMENTS IN RECIPROCATING MACHINES**

The present invention relates to reciprocating machines and, more particularly, to vacuum pumps which incorporate a reciprocating piston.

Vacuum pumps incorporating a reciprocating piston mode of operation are known which have an electromagnetic actuator arrangement driving a piston.

In European patent publication no. 0793019 there is described a vacuum pump which uses a multi-stage reciprocating piston mode of operation in which piston reciprocation is effected by electromagnetic drive means and a counter-acting spring means and in which the pump stages are connected in series between a pump inlet and a pump outlet such that, in use, gas being transferred through the pump passes through the stages in turn.

It is an aim of the present invention to provide a machine and more particularly a vacuum pump incorporating a reciprocating piston in which a vibration sensor is used to control the piston stroke and thus avoid over driving the machine/vacuum pump.

According to the present invention, a machine comprises a cylinder closed at both ends, a piston mounted for reciprocable movement within the cylinder between each end, means for driving the piston and a vibration sensor for sensing any contact between the piston and said ends.

In a preferred embodiment the machine is a vacuum pump, the vibration sensor is a piezoelectric device and the driving means includes an electro-magnet.

Preferably, the machine is driven by a closed loop control including the vibration sensor, a variable drive and an electronic circuit which is used to analyse the vibration sensor output signal to determine the drive voltage.

An embodiment of the invention will now be described, by way of example reference being made to the Figure of the accompanying diagrammatic drawing which is a schematic illustrating the relationship between the drive means, reciprocating piston, vibration sensor and controller of a machine according to the present invention.

As shown a vibration sensor 3 for example a piezoelectric device is mounted on a machine in the form of a pump 1, such that any end collision of reciprocation piston 5 is detected, for example on the end of the pump. Vibration sensor 3 is electrically/electronically connected to a controller 2 in the form of an electronic circuit, for example a micro-processor. In turn, the controller 2 is electrically/electronically linked to a variable voltage drive means 4 including an electromagnet which is itself mechanically linked to the piston 5 of the pump 1, to form a closed loop control system.

In use, the controller 2 is set to deliver a gradually increasing voltage across the drive means 4. This has the effect of gradually increasing the stroke length of the piston 5. Should the end of the piston 5 strike an end plate (not shown) at either end of the pump 1 this is detected by the vibration sensor 3 which generates a signal which is transmitted to the controller 2. Receipt of said signal from the vibration sensor 3 then causes the controller 2 to reduce the drive voltage to the drive means 4.

It will be apparent that, in the above described embodiment, the pump 1 is driven by a closed loop control system which includes a vibration sensor 3, a variable drive means 4 and a controller 2 which is used to analyse the sensor output to determine the drive voltage.

The vibration sensor 3 is effectively used to maximise the piston stroke by sensing any end point engagement and thereby avoiding over driving the pump. The vibration sensor 3 is able to detect collision at either end, therefore the maximum stroke is achieved independent of any offsets in the system.

Although reference is made in the above described embodiment to a variable voltage drive means, said drive means could be a variable current drive.

The benefits of the control means are:

- optimum performance of the machine is achieved through maximised stroke length.
- the closed loop control provides inherent compensation for mechanical load and power supply variations.
- the vibration sensor 3 is not intrusive, therefore not vulnerable to contamination or corrosive attack.
- the vibration sensor 3 does not require accurate calibration or positioning indeed the sensor may be mounted on any appropriate surface of the machine.
- the electronic controller may detect vibration sensor failure or detachment by monitoring the background vibration level from the sensor 3.
- the closed loop control provides inherent compensation for change in mechanical performance over time.
- The closed loop control requires minimal set up in manufacture and service.

**CLAIMS**

1. A machine comprising a cylinder closed at both ends, a piston mounted for reciprocable movement within the cylinder towards and away from said ends, means for driving the piston and a vibration sensor for sensing any contact between the piston and said ends.
2. A machine as claimed in Claim 1, in which the driving means is a variable voltage or current drive means controlled by signals from a controller.
3. A machine as claimed in Claim 2, in which the vibration sensor, the controller and the variable voltage/current drive means define a closed loop control system.
4. A machine as claimed in Claims 1 or Claim 2 or Claim 3, in which the vibration sensor is mounted on the machine adjacent a closed end, such that it is not invasive to the internal operation of the machine.
5. A machine as claimed in any one of Claims 1 to 4 in the form of a vacuum pump.
6. A machine constructed, arranged and adapted to operate substantially as hereinbefore described with reference to and as illustrated in the Figure of the accompanying drawing.



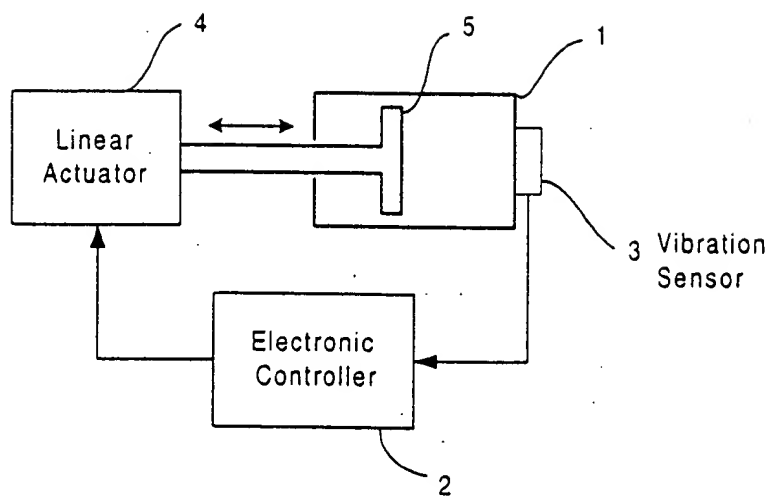


Figure 1